A Hadron Blind Detector for PHENIX

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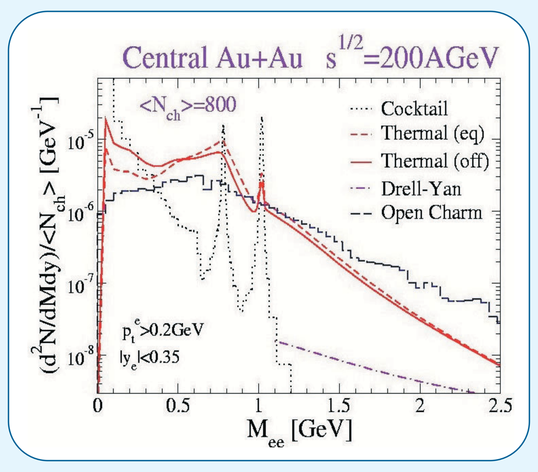
Motivation

- low-mass e^+e^- pairs are the best probe for the study of CSR
- the RHIC program will be incomplete without a good measurement of low-mass e^+e^- pairs
- PHENIX is the only experiment at RHIC that can perform such measurement

PHENIX is developing a Hadron Blind Detector (HBD) to allow a good measurement of low-mass e^+e^- pairs (the HBD will reject the combinatorial background from π^0 Dalitz and conversions by ~ two orders of magnitude):

Low-mass e⁺e⁻ Pairs: Prospects at RHIC



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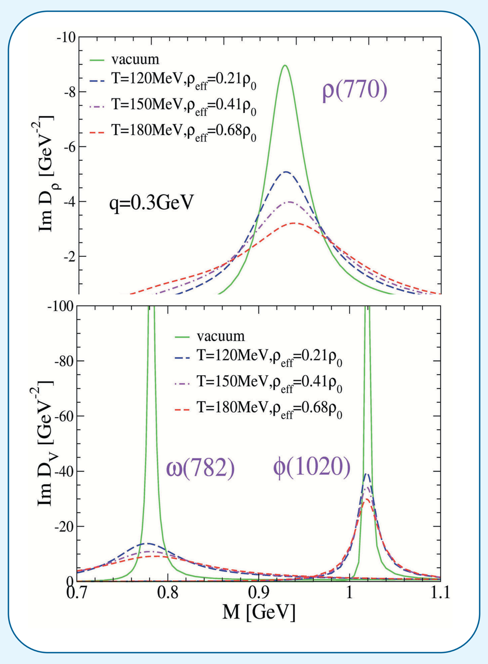
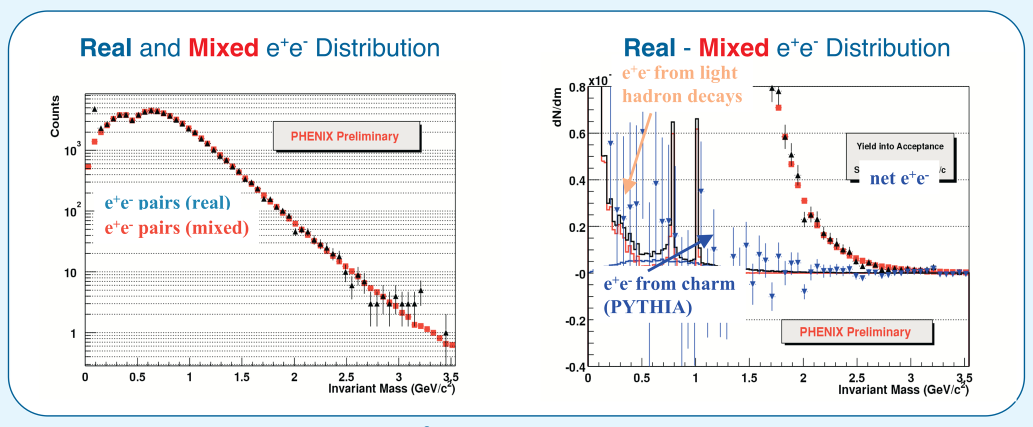


- Strong enhancement of low-mass pairs persists at RHIC (baryon density is almost the same at RHIC and SPS)
- Contribution from open charm becomes significant

Performance of Present PHENIX set-up



Low-mass pairs: (0.3 – 1.0 GeV/c²):

S/B~1/100 -- 1/500 depending on p_t cut and mass.

The present set-up lacks the means to identify and reject the overwhelming electron yield originating from π^0 Dalitz decays and γ conversions

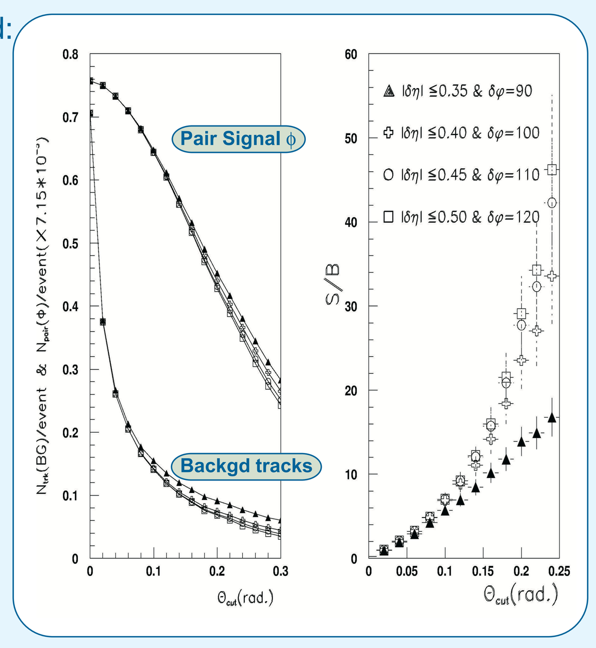
HBD will impove S/B by ~2 orders of magnitude

(Monte Carlo: Signal ϕ meson, Background: γ conversions and π^0 Dalitz only)

- Inner detector:
  - * perfect e-id ε= 100 %
  - * perfect dhr = 0 mrad
  - * π rejection = ∞
  - * plus veto area

$|\delta\eta| \leq 0.40$ and $\delta\phi \leq 100°$

The number of tracks from π^0 Dalitz and conversions is reduced by almost a factor of 20.



Upgrade Concept

Hardware

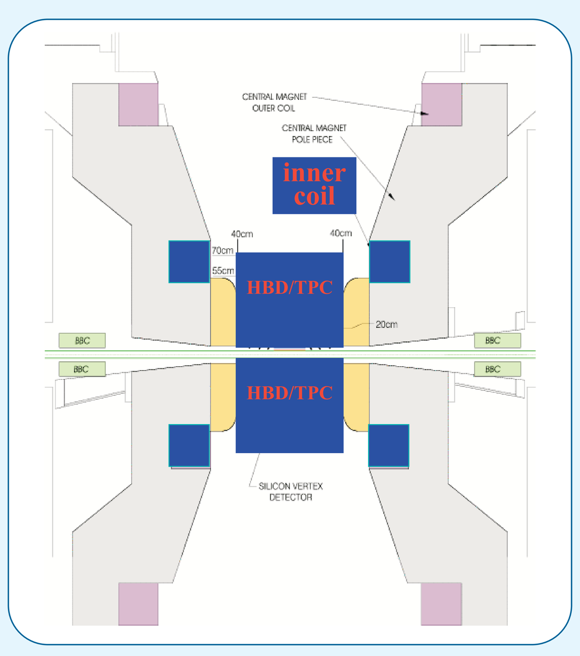
- Create field free region with **inner coil** (foreseen in original design B~0 for ≤ 50-60cm)
- Compact **HBD** in inner region (to be complemented by a TPC).

Specifications

- Electron efficiency ≥ 90%
- Double hit recognition ≥ 90%
- Modest π rejection ~ 200

Strategy

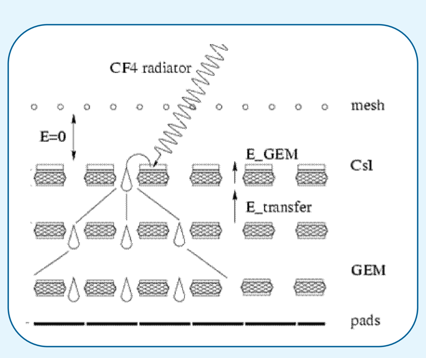
- Identify signal electrons (low mass pairs) with p>200 MeV in outer PHENIX detectors
- Identify low-momentum electrons (p<200 MeV) in HBD
- Reject pair if opening angle < 200 mrad (for a 90% rejection).



Detector concept:

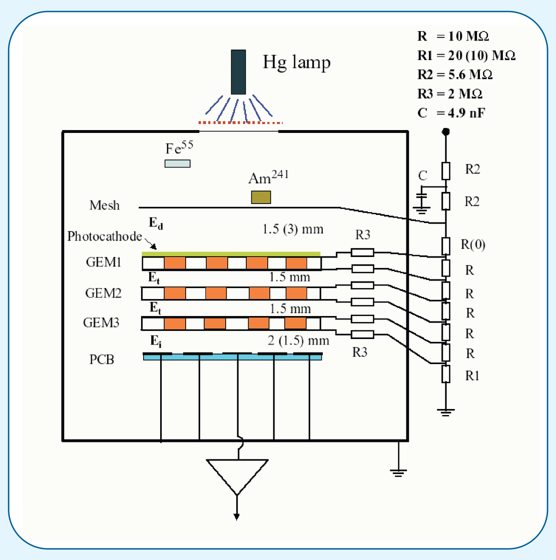
- Windowless Cherenkov detector (L=50cm)
- CF_4 as radiator and detector gas
- CsI reflective photocathode
- Triple GEM with pad readout

Bandwidth 6-11eV, $N_0 \approx$ 940cm⁻¹ ➡ Npe ≈40!
No photon feedback
Low granularity, relatively low gain



R&D Set-up

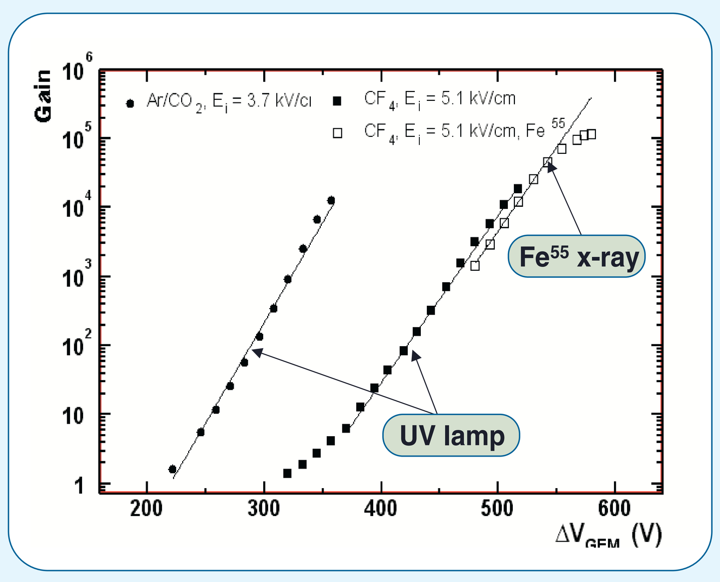
Detector Box



- Use 3x3 and 10x10 cm² GEM foils produced at CERN
- Test with Fe^{55}, Am^{241} α source, UV lamp and cosmic rays
- GEMs powered with resistive chain

Gain Curve: Triple GEM with CsI in CF_4

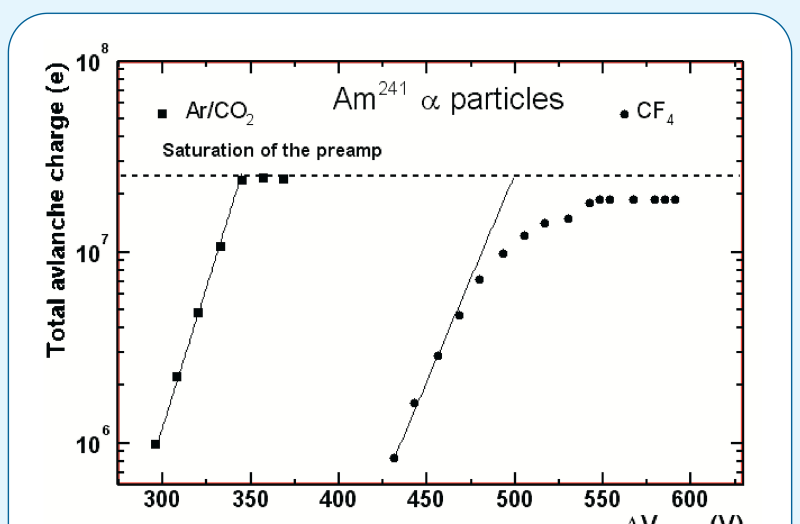
measured with Fe^{55} and with UV lamp



- Pretty good agreement between gain measured with Fe^{55} and UV lamp.
- Gains in excess of 10^4 are easily attainable.
- Voltage for CF_4 is ~ 140 V higher than for Ar/CO_2 but slopes are similar for both gases.
- Gain increases by factor ~3 for V = 20V

Total Charge in Avalanche

in Ar/CO_2 and CF_4 measured with Am^{241}



Charge saturation in CF_4 !!!

- In Ar/CO2 the total charge increas exponentially and it is saturated by the preamplifier
- In CF_4 when the total charge exceeds 4 x 10^6 a deviation from exponential growth is observed leading to gain saturation when the total charge is ~2x10^7.

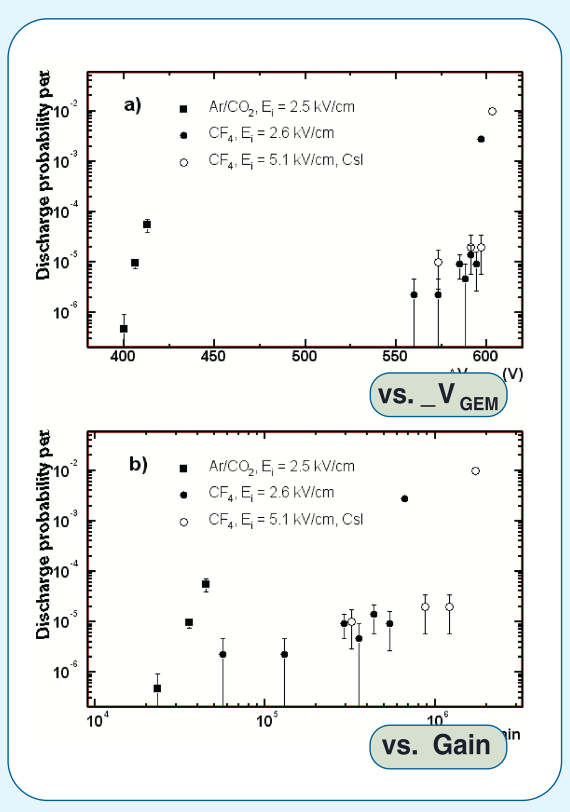
Discharge Probability

- Stability of operation and absence of discharges in the presence of heavily ionizing particles is crucial for the operation of the HBD.
- Use Am^{241} to simulate heavily ionizing particles.

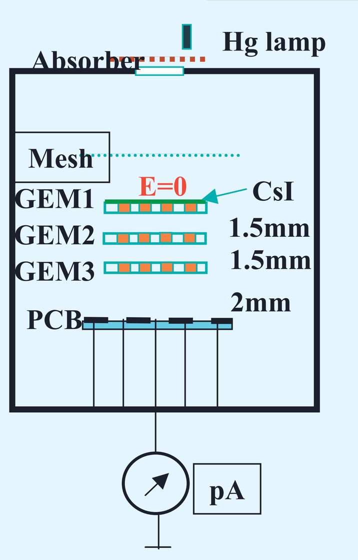
➡ In Ar/CO_2, the discharge threshold is close to the Raether limit (at~10^8), whereas in CF_4 the discharge threshold seems to depend on GEM quality and occurs at voltages ΔV_{GEM} =560-600V

➡ CF_4 more robust against discharges than Ar/CO_2.

HBD expected to operate at gains < 10^4 i.e. with very comfortable margin below the discharge threshold



Ion back-flow

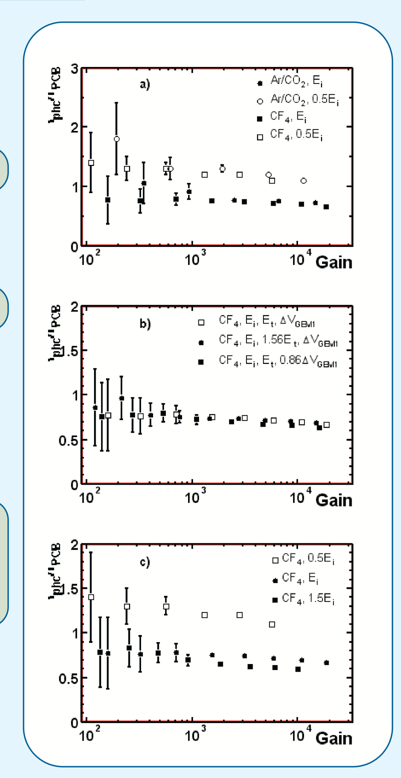


Fraction of ion back-flow defined here as: I_{phc} / I_{PCB}

Independent of gas

Independent of E_t

Depends only on E_i (at low E_i some charge is collected at the bottom face of GEM3)

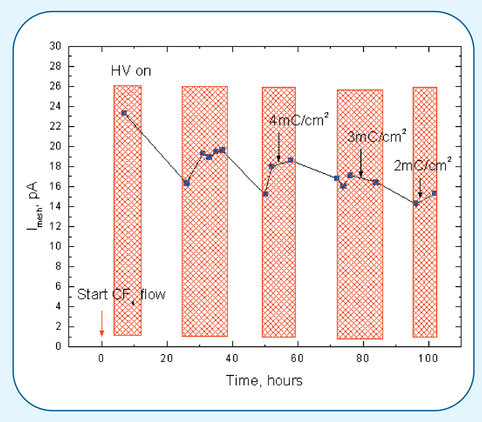


Ions seem to follow the electric field lines. In all cases, ion back-flow is of order 1!!!

Aging

CsI photocathode

- In spite of the large ion back-flow there is no dramatic deterioration of the CsI quantum efficiency (QE).
- For a total irradiation of ~10mC/cm², the QE drops by only 20%. (The total charge in 10 years of PHENIX operation is conservatively estimated to 1mC/cm².)

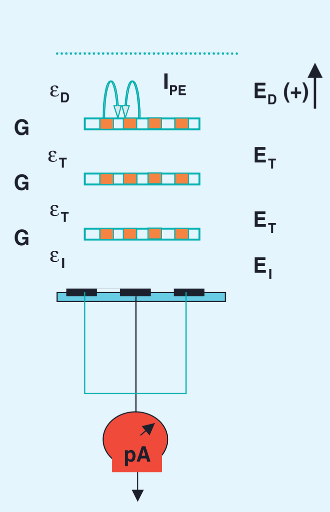


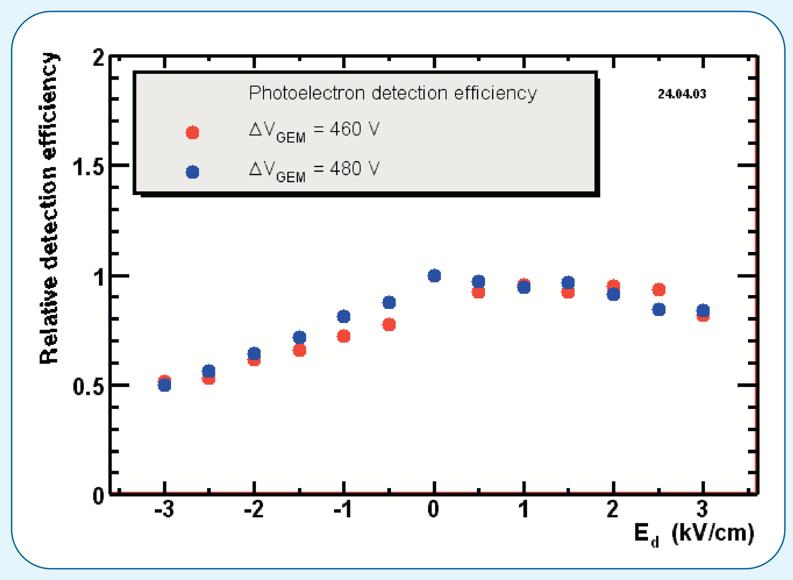
GEM foils

- During the whole R&D period we never observed aging effects (e.g. loss of gain) on the GEM foils. Total irradiation was well in excess of 10mC/cm².

Single Photoelectron Detection Efficiency

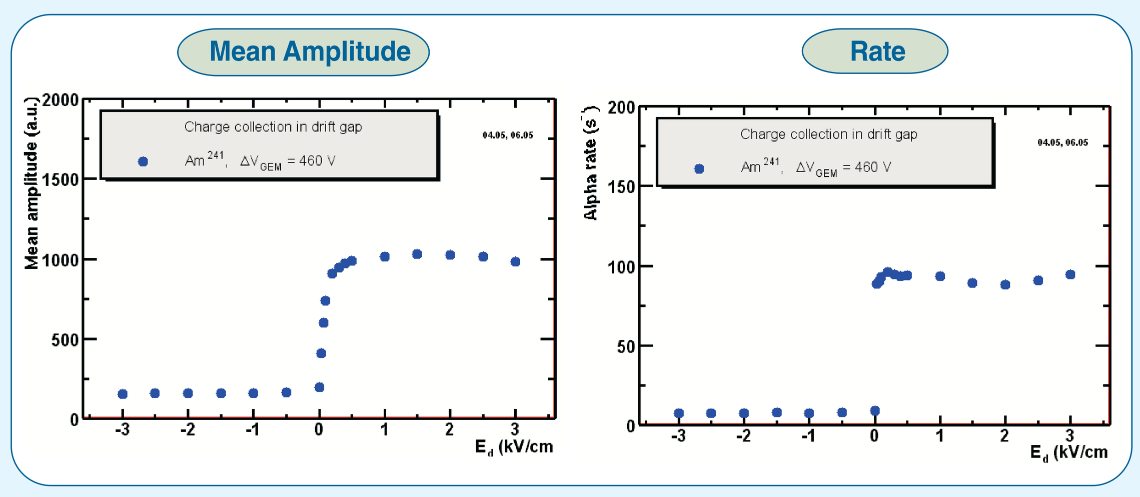
measure detector response vs E_D at fixed gain





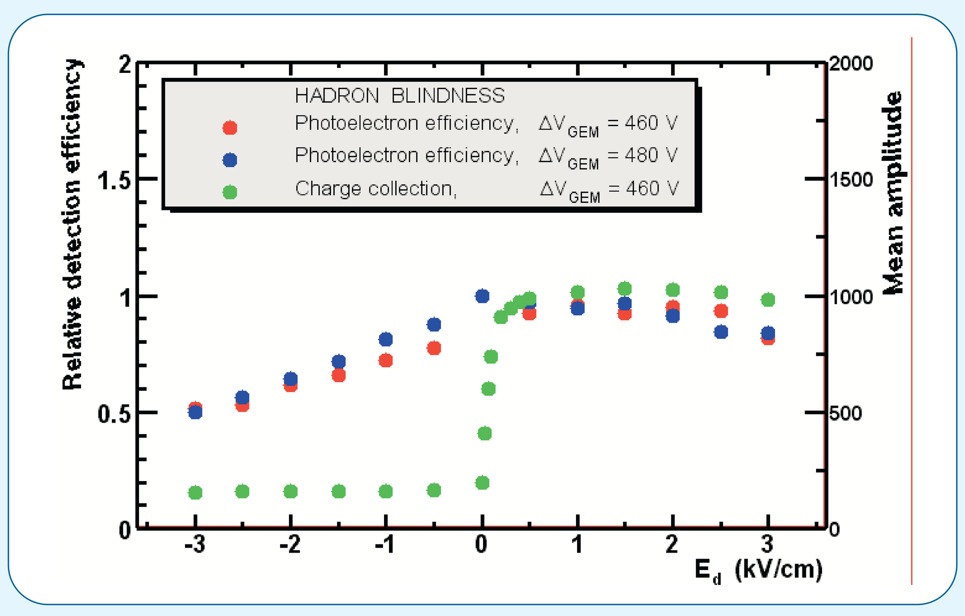
Very efficient detection of photoelectrons even at negative drift fields !!

Charge Collection in Drift Gap



At E_D = 0: - signal drops dramatically as anticipated.
- rate also drops dramatically
➡ large hadron suppression

Hadron Blindness: UV photons vs. particles



At slightly negative E_D, photoelectron detection efficiency is preserved whereas charge collection is largely suppressed.

Present HBD design